Transparency in high capacity networks based on an optical layer

Bjarke Skjoldstrup[1], Jan Späth[2] and Admela Jukan[3]
[1]Tele Danmark, R&D Network Technologies, DK-2630 Taastrup, Denmark
Tel: +45 43 34 54 13, fax: +45 43 52 80 76, e-mail: bjsk@u.tdk.dk
[2]University of Stuttgart, Institute of Communication Networks and Computer Engineering
Pfaffenwaldring 47, D-70569 Stuttgart, Germany
Tel: +49 711 685 7990, fax: +49 711 685 7983, e-mail: spaeth@ind.uni-stuttgart.de
[3]Vienna University of Technology, Institute of Communication Networks
Gusshausstr. 25/388, A-1040 Vienna, Austria
Tel. +43-1-58801-3993, Fax. +43-1-587 05 83 Austria, e-mail: admela.jukan@tuwien.ac.at

The performance requirements, in the past traditionally put on client signals in telecommunication networks, are now moving to requirements on networks themselves. One important requirement is the network transparency. We present an approach to define different levels of transparency for high capacity networks based on optical layers and apply these definitions to a network segment example.

Introduction

Since the interest of large business customers in accessing optical fibre networks is permanently increasing, the network operators must be able to provide various services for them in the near future. But by introducing optical network layers, the network planning is becoming more complex because of the analog nature of optical signals in WDM networks. The physical constraints in terms of signal-to-noise ratio, crosstalk, reflections, etc. must be taken into consideration on an end-to-end basis for all connection requests.

The transparency of connections in optical networks is an important issue for network planning and management. From the point of view of network providers, the specification of network transparency is a key issue for network upgrade scenarios. The reason is, that a network upgrade focusing only on the support of specific (already existing) signals could lead to an unintended reduction of the network ability to transport other signal types.

In this paper, the concept of transparency in the context of telecommunication networks is explained first. Then, a definition of signal transparency is given and a method for classifying optical network connections is presented. Finally, an example of an optical network segment including semiconductor optical amplifiers (SOAs) is shown and the transparency of this segment is identified according to the definitions suggested.

What is transparency in telecommunication networks?

The fundamental task of a telecommunication network is to provide the infrastructure for transferring information between traffic sources and sinks. Transparent information transfer refers to the independence of the method chosen for transporting the information within the network. The concept of full transparency refers to a network entity operating completely independent of service type, signal or frame format, coding scheme, bit rate, etc. [1]. Full transparency of telecommunication networks can therefore hardly be achieved.

Often, the transparency of a network connection is expressed as the capability of the network to maintain the quality of a client signal during transmission. If the signal originating from client network is digital, the signal quality can be easily maintained by using digital regenerators. However, from a certain point of view, a connection that only supports digital signals is not a 'transparent' one since analog signals cannot be transferred on it. Furthermore, a certain connection may only support a very limited range of digital transmission rates. According to this, transparency can be considered as the ability of supporting various signal types or as the ability of maintaining a specified level of quality for a certain signal type.

In the ITU-T/ETSI standards referring to the functional descriptions of network architectures these two aspects have been covered by defining the *adaptation function* and the *termination function* [2]. Each network layer is characterised by having at least one set of adaptation and termination functions. The adaptation function takes care of the physical aspects in adapting and converting signals from one type to another and the termination function provides the means for securing the integrity of the communication within the considered network layer.

Let us consider the layering of the optical network according to [3], as shown in Figure 1. Each layer has its own task of adapting or terminating the signals transported. The following is a very simplified explanation of the basic functions of these three optical layers. The Optical Channel Layer (OCL) converts the electrical client signal into an optical signal. This signal is assigned to a wavelength by the Optical Multiplex Section Layer (OMSL) which provides the ability to wavelength multiplex the optical signals into one fibre. In the Optical Transmission Section Layer (OTSL), the signals are amplified and fibre dispersion is accommodated.

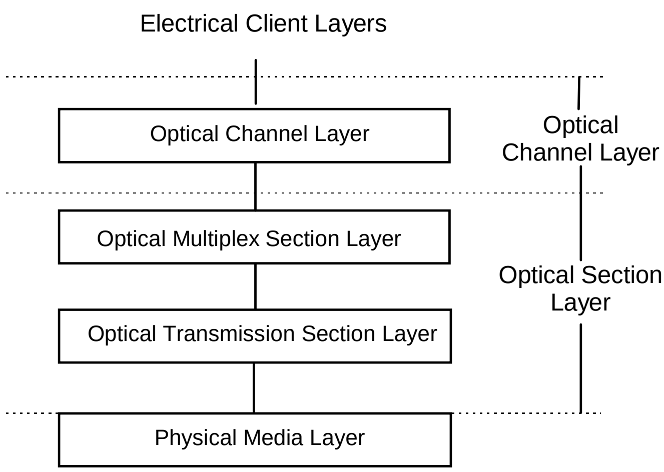

Figure 1: *Three new layers in optical transport networks*

The adaptation and termination functions are typically symbolised by trapeziums and triangles as shown in the functional description of the Optical Channel Layer in Figure 2. From the point of view of operation and maintenance, the signal quality is controlled by using the overhead information generated and processed by termination functions of the network layer under consideration. This helps network operators to get a picture of the quality level of signals handled. In case of signal quality degradation, the appropriate actions for failure detection and restoration are supported with termination functions.

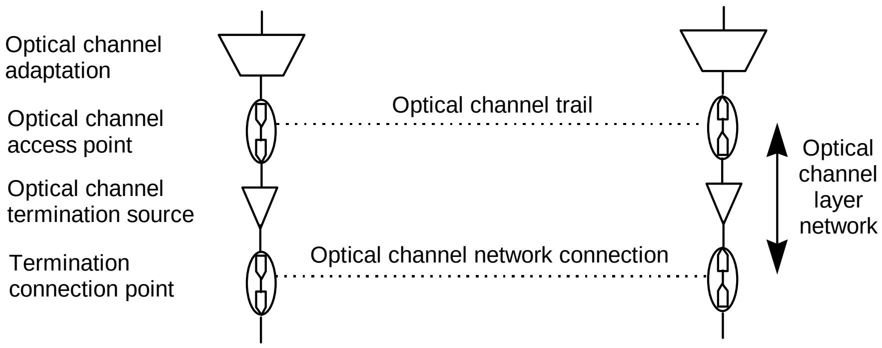

Figure 2: *Functional description of the Optical Channel Layer (OCL)*

Physical network segments are implemented with a limited built-in support of signal types represented by the adaptation functions in the functional description of the network elements. The network provider must take into account the upgradeability of the telecommunication network when selecting the hardware solutions for network elements. In particular, the limitation in support of different signal *types* is more difficult to overcome than the limitations of signal *quality* once the network elements are installed. Network upgrading should be easier if the transparency through the adaptation is defined from the network planning start on. In the next section, this is explained in more detail.

Definition of adaptation transparency

First of all, a transparent network must support the information bearing properties of a signal. These properties are accommodated by the adaptation functions of the network layers and can be structured hierarchically according to the signal characteristics. This hierarchy describes what we define as *adaptation transparency*. The highest level of this hierarchy stands for the support of the physical nature of information bearing carriers (wired, wireless, optical, electrical etc.). The assistance of signal type (analog or digital), modulation format, line code, bandwidth/bit-rate, transmission type and transmission format follows further down the hierarchy, as shown in Figure 3.

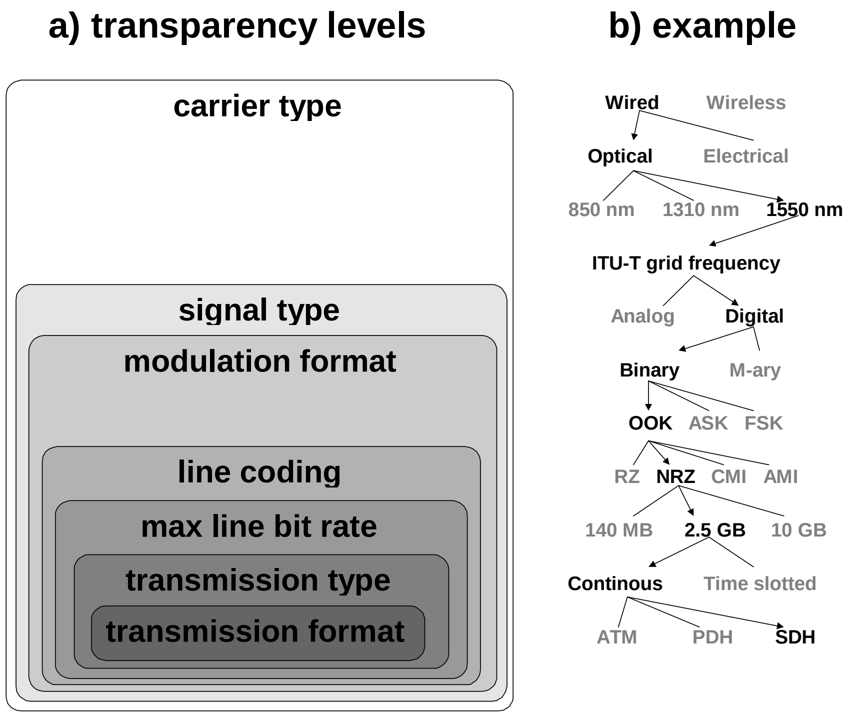

Figure 3: *a) hierarchical classification of information bearing properties of a signal, b) example of a STM–16 (2.5 Gbit/s SDH) connection implemented by using WDM networks*

As an example of how to map a network connection to this hierarchy, an SDH network connection (an STM-16 system implemented in a WDM channel) is also shown in Figure 3. Note that the transparency of the network decreases towards the bottom of the hierarchy, where the adaptation becomes more specific. According to [1], the following grades of transparency can be defined (although for some applications it might be appropriate to choose the hierarchical order different from the one suggested here):

1 T -transparent — Transparent regarding transmission format

2 T -transparent — Transparent regarding transmission type and format

3 T -transparent — Transparent regarding line rate/bandwidth, transmission type and format

4 T -transparent — Transparent regarding line code, line rate/bandwidth, transmission type and format

5 T -transparent — Transparent regarding modulation format, line code, line rate/bandwidth, and transmission format

6 T -transparent — Transparent regarding signal type, modulation format, line code, line rate/bandwidth, and transmission format

7 T -transparent — Transparent regarding the optical carrier signal type, modulation format, line code, line rate/bandwidth, and transmission format

It is generally accepted that the line rate/bandwidth is an important transparency parameter, but in a strict sense all components have a limited bandwidth. In order to talk about transparency regarding line rate/bandwidth it is therefore required to specify the maximum bandwidth referred to. Moreover, the method suggested here treats the transparency of each network element separately. However, the cascading of several elements with the same level of transparency may reduce the overall level of transparency due to bandwidth narrowing, ASE accumulation, etc. This problem is similar to BER accumulation. In a reconfigurable architecture these effects are not static and therefore they should be treated as signal quality degradation. Overhead bytes for tracking and monitoring the signal quality parameters in the optical network layer should also consider these effects.

Network segment example

In the following, we consider an optical network segment composed of a WDM multiplexer (without optical amplification), an in-line amplifier, an optical cross-connect with wavelength conversion capability, and an optical add-drop multiplexer. The specific implementation is assumed to support signals with a maximum bit rate of 10 Gbit/s. The optical amplifier and the wavelength converter in the cross-connect are all based on SOAs. Three types of SOA based wavelength converters are normally distinguished: converters utilising cross-gain, cross-phase, or coherent mixing/four-wave mixing. The latter type of converters (based on coherent/four-wave mixing) is not considered here due to the strong polarisation dependence. The classification of the different levels of adaptation transparency defined in the previous section is applied to the network segment as shown in Figure 4.

The adaptation transparency of the network segment in Figure 4 is limited by the optical cross-connect due to the SOA based wavelength converter. The primary reason for the limitation is not the digital nature of the wavelength converter but the fact that the conversion capability is bit rate limited. This means that transmission type and transmission format of a signal can be chosen freely, but bit rate, modulation format, signal type and carrier type have to fulfil the specifications for a network segment. The limitation in the transparency of the in-line SOA and the add-drop multiplexer is due to the lack of support of analog signal types.

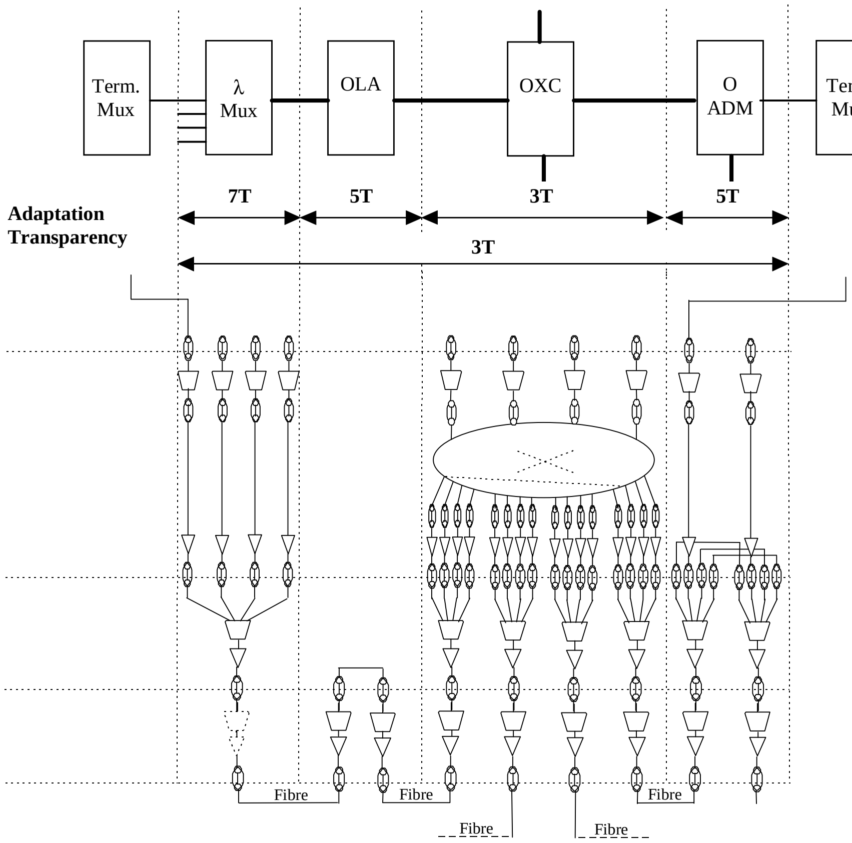

Figure 4: *Classification of adaptation transparency of an optical network segment*

Conclusion

This paper discussed some transparency aspects for telecommunication networks. A definition of the capability of a network to support information bearing properties of a signal was given from the point of view of transparency. This is called *adaptation transparency*. Seven classes of transparency were defined and mapping of an optical network segment example onto these classes was shown. The transparency of a segment in optical networks is limited by the network element with the lowest transparency level ('transparency bottleneck'). In this way, the influence of network upgrades on the level of network transparency can be easily determined. Moreover, this is an important pointer to the design of optical network components, where the definition of transparency level is necessary.

Acknowledgement

The second author thanks the German BMBF (Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie) for support of this work under contract 01BP 504/2.

References

[1] Mathias Bishoff et. al.: "Operation and Maintenance for an All-Optical Transport Network" IEEE Communications Magazine, November 1996 pp. 136 - 142

[2] ITU Recommendation G.805, "Generic Functional Architecture of Transport Networks", Geneva, November 1995

[3] ITU-T Draft Recommendation G.otn, "Architecture of Optical Transport Networks" Turin, June 1997